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Single ion implantation with low energy highly charged ions

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Single ion implantation offers the possibility to position individual donor atoms into a solid with high spatial resolution. A key issues is the efficiency with which ions can be detected as a function of impact energy. In our presentation we will report on our development of a low energy (<20 keV), single ion implantation scheme for $^{31}P^{q+}$ ions. When $^{31}P^{q+}$ ions impinge on a wafer surface, their potential energy (9.3 keV for P^{15+}) is released, and about 20 secondary electrons are emitted. The emission of multiple secondary electrons allows the detection of each ion impact with 100% efficiency. Secondary electron emission results from deposition of potential energy and secondary electron yields are largely independent of the kinetic energy of projectiles. The beam spot on target is controlled by beam focusing and collimation. Exactly one ion is implanted into a selected area avoiding a Poissonian distribution of the number of implanted ions. Secondary electrons are detected in an annular microchannelplate detector. Spot size limiting apertures are formed in thin (~100 nm) low stress silicon nitride membranes by reactive gas assisted focused ion beam (FIB) milling with 30 keV Ga^+ ions. Preliminary data suggest an aspect ratio limit of FIB of about 4:1 for 200 nm thick membranes.

Several solid state quantum computer schemes are based on the manipulation of electron and/or nuclear spins of single ^{31}P atoms in a solid matrix (e. g., Si or Si_xGe_y hetero-structures), and our work focuses on the formation of ^{31}P qubit arrays. Key issues of process integration (implant alignment, annealing and gate formation) for qubit arrays with control and readout structures for prototype multi-qubit devices will be discussed.

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